

IMAGE FORMING APPARATUS

BACKGROUND OF THE INVENTION

Field of the Invention

5 This invention relates to an image forming apparatus such as a copying machine or a printer, and particularly to an apparatus for transferring an image on an image bearing member to a transfer material.

10 Description of Related Art

 Fig. 4 of the accompanying drawings shows an image forming apparatus which is the background art of the present invention.

 This image forming apparatus has a plurality of
15 photosensitive drums 111a, 111b, 111c and 111d as first image bearing members corresponding to developers (toners) of the first color: yellow, the second color: magenta, the third color: cyan, and the fourth color: black, and an intermediate transferring
20 belt 101 as a second image bearing member, and the intermediate transferring belt 101 is in contact with each of the photosensitive drums 111a-111d in respective primary transferring parts.

 The photosensitive drums 111a-111d are disposed
25 along the direction of movement of the intermediate transferring belt 101 in the order of the photosensitive drum 111a for the first color (yellow)

located most upstream, the photosensitive drum 111b
for the second color (magenta) located nearest to and
downstream of the photosensitive drum 111a, the
photosensitive drum 111c for the third color (cyan)
5 located nearest to and downstream of the
photosensitive drum 111b, and the photosensitive drum
111d for the fourth color (black) located nearest to
and downstream of the photosensitive drum 111c.

Also, the intermediate transferring belt 101 is
10 located at a predetermined process speed in
synchronism with the photosensitive drums 111a-111d.

The photosensitive drums 111a, 111b, 111c and
111d are uniformly charged by contact charging
rollers 112a, 112b, 112c and 112d, respectively, and
15 electrostatic latent images are formed on the
surfaces thereof by laser beams from scanners 113a,
113b, 113c and 113d modulated by an image information
signal sent from a host computer.

These electrostatic latent images reach
20 portions opposed to developing devices 114a, 114b,
114c and 114d by the rotation of the photosensitive
drums 111a-111d, and are supplied with toner charged
to the same polarity (the minus polarity in this
example) as that of the surfaces of the
25 photosensitive drums 111a-111d, and are visualized
thereby and become developer images (toner images).
The developing devices 114a-114d provided for the

respective photosensitive drums 111a-111d are of a two-component developing type, and perform their developing operation by a developing bias comprising an AC voltage superimposed on a DC voltage being
5 applied thereto.

The toner images formed on the respective photosensitive drums 111a-111d are transferred onto the intermediate transfer belt 101 by a primary transferring bias being applied from primary
10 transferring bias sources 116a, 116b, 116c and 116d to primary transferring rollers 115a, 115b, 115c and 115d, respectively, which are in contact with the back of the intermediate transferring belt 101, in respective primary transferring nips formed by and
15 between the intermediate transferring belt 101 and the photosensitive drums 111a-111d. At a stage whereat the intermediate transfer belt 101 has passed the primary transferring nip between it and the photosensitive drum 111d, the formation of a four-
20 color image on the intermediate transferring belt 101 is terminated, and a primary transferring step is completed.

Next, a transfer material M is taken out of feeding means, not shown, and is inserted into a
25 secondary transferring nip portion formed by a separation roller 101c and a secondary transferring roller 102 as a transferring member being brought

into pressure contact with each other with the intermediate transferring belt 101 interposed therebetween. At this time, a bias opposite in polarity to the toners is applied to the secondary
5 transferring roller 102 by a secondary transferring bias source 121, whereby the toner image is secondary-transferred from the intermediate transferring belt 101 to the transfer material M.

The transfer material M bearing the unfixed
10 toner image thereon and having left the secondary transferring nip portion arrives at a fixing apparatus 103, and is heated and pressurized thereby, whereby a permanent fixed image is obtained.

Each of the photosensitive drums 111a-111d has
15 an outer diameter of 30.0 mm and has a layer having a photosensitive material applied thereto on an aluminum cylinder.

The intermediate transferring belt 101, as shown in Fig. 2, is passed over three rollers
20 contained in the intermediate transferring belt 101, i.e., a drive roller 101a, a supporting roller 101b and a separation roller 101c.

As the intermediate transferring belt 101, carbon is dispersed in polyimide and the surface
25 resistivity ρ_s thereof is adjusted to medium resistance of $1 \times 10^{12} \Omega$, whereby charges added to the belt with the transferring step or the like can be

attenuated without providing any special residual charge eliminating mechanism. Also, the intermediate transferring belt 101 is a single-layer endless belt having a circumferential length of 1000 mm and a
5 thickness of 100 μm .

Each of the drive roller 101a, the supporting roller 101b and the separation roller 101c over which the intermediate transferring belt 101 is passed is a roller having an outer diameter of 29.8 mm and
10 comprised of an aluminum mandrel having a diameter of 24.0 mm and an elastic layer having a layer thickness 2.9 mm. Also, the secondary transferring roller 102 is a roller having an outer diameter 33.0 mm and comprised of an aluminum mandrel having a diameter of
15 14.0 mm and a rubber layer having a layer thickness of 9.5 mm, and the hardness of this roller is 26° (Asker-C).

The intermediate transferring belt 101 in the present example is of a single-layer construction in
20 which Young's modulus E is $6 \times 10^9 \text{ N/m}^2$. Also, the contact pressure P [N/m^2] of the secondary transferring roller 102 in the present example relative to the intermediate transferring belt 101 is $3.3 \times 10^4 \text{ N/m}^2$.

25 The contact pressure P is given as $P = F / (L \times W)$ from the lengthwise width L [m] of the secondary transferring roller 102, the nip width W [m] between

the intermediate transferring belt 101 and the secondary transferring roller 102, and the contact force F [N] of the secondary transferring roller 102 relative to the intermediate transferring belt 101.

5 Also, the nip width W was obtained by applying ink to the intermediate transferring belt 101 and bringing the secondary transferring roller 102 into contact therewith, and measuring the trace of the ink adhering to the secondary transferring roller 102.

10 The nip width W was determined from the average of the widths of the trace of the ink measured at five points in total, i.e., the center of the roller, points of 50 mm from the center toward the right and left lengthwise ends, and a point of 100 mm from the

15 center toward the right and left lengthwise ends. In the present example, $L = 0.30$ m, $F = 50$ N, and $W = 0.0050$ m.

 In the above-described image forming apparatus of the electrophotographic type, the stabilization of

20 the conveyance of the transfer material in the secondary transferring step is achieved by securing a wide nip width of 5.0 mm of the secondary transferring roller 102 by the use of a roller of low hardness of 26° (Asker-C) as the secondary

25 transferring roller 102, and prevents the occurrence of a faulty image attributable to the conveyance shock of the transfer material.

On the other hand, a material of high hardness which the Young's modulus E is $6 \times 10^9 \text{ N/m}^2$ is used for the intermediate transferring belt 101 to thereby prevent the destruction of the belt due to the
5 fracture thereof, thereby achieving an intermediate transferring belt having a long life.

Now, when the intermediate transferring belt 101 of high hardness is used as described above, if a roller of low hardness is used as the secondary
10 transferring roller 102, the nip width become liable to widen and therefore, this has led to a case where the contact pressure P of the secondary transferring roller 102 assumes a low value and the color unevenness of an image attributable to the secondary
15 transferring step is caused.

This color unevenness caused during the secondary transferring step is considered to be attributable to the unevenness of the surface of the transfer material.

20 That is, the surface of the transfer material M and the surface of the intermediate transferring belt 101 cannot uniformly contact with each other due to the unevenness of the surface of the transfer material M and the high hardness of the intermediate
25 transferring belt 101 and therefore, depending on locations, air gaps exist between the surface of the transfer material M and the surface of the

intermediate transferring belt 101.

At locations whereat air gaps exist between the toner layer on the intermediate transferring belt 101 and the surface of the transfer material, a
5 transferring electric field originally applied to only the toner layer is divided by an air layer, whereby the electric field applied to the toner layer is weakened, and the amount of toners residual on the intermediate transferring belt 101 becomes great.
10 This is because unless the reversal of the polarity of the toners occurs, the amount of toners transferred from the intermediate transferring belt 101 to the transfer material M becomes greater when the transferring electric field applied to the toner
15 layer is greater.

It is considered that if as described above, the contact state between the surface of the transfer material M and the surface of the intermediate transferring belt 101 is partly non-uniform, the
20 untransferred toners also become non-uniform. The difference by the portions of the toners not secondary-transferred at this secondary transferring step is considered to be the cause of the occurrence of the uneven colors of an image.

25 Consequently, in the above-described example, a roller of low hardness is adopted as the secondary transferring roller 102, whereby the contact pressure

P assumes a low value and it becomes difficult for the unevenness of the surface of the transfer material M to follow the surface of the intermediate transferring belt 101, whereby the contact state
5 between the surface of the transfer material M and the intermediate transferring belt 101 becomes non-uniform and the residual toners on the intermediate transferring belt 101 also become non-uniform and therefore, the uneven colors are considered to occur.

10

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an image forming apparatus which prevents the deterioration of an image even if it uses an image
15 bearing member of high hardness.

It is another object of the present invention to provide an image forming apparatus which is provided with an image bearing member bearing an image thereon, and a transferring member contacting
20 with the image bearing member in a contact portion, and in which the image on the image bearing member is transferred to a transfer medium in the contact portion by the transfer member, the Young's modulus of the image bearing member is equal to or greater
25 than 2×10^8 [N/m²] and equal to or less than 9×10^9 [N/m²], and the contact pressure between the image bearing member and the transfer member in the contact

portion is equal to or greater than 4.0×10^4 [N/m²]
and equal to or less than 7.3×10^4 [N/m²].

It is another object of the present invention
to provide an image forming apparatus which is
5 provided with an image bearing member bearing an
image thereon, and a transfer member contacting with
the image bearing member in a contact portion, and in
which the image on the image bearing member is
transferred to a transfer medium in the contact
10 portion by the transfer member, the surface
resistivity of the image bearing member is equal to
or greater than 1×10^8 [Ω] and equal to or less than
 1×10^{15} [Ω], and the contact pressure between the
image bearing member and the transfer member in the
15 contact portion is equal to or greater than 4.0×10^4
[N/m²] and equal to or less than 3×10^4 [N/m²].

Further objects of the present invention will
become apparent from the following description.

20 BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows an image forming apparatus which
is an embodiment of the present invention.

Fig. 2 is a perspective view of a secondary
transferring part.

25 Fig. 3 shows a secondary transferring part in
another embodiment.

Fig. 4 shows an image forming apparatus which

is the background art of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

An image forming apparatus which is an
5 embodiment of the present invention will hereinafter
be described in detail with reference to the drawings.
(First Embodiment)

The construction of an image forming apparatus
according to the present embodiment will first be
10 described with reference to a schematic cross-
sectional view of a full-color electrophotographic
image forming apparatus shown in Fig. 1.

The image forming apparatus has a plurality of
photosensitive drums 11a, 11b, 11c and 11d as first
15 image bearing members corresponding to color toners
of a first color: yellow, a second color: magenta, a
third color: cyan, and a fourth color: black, and an
intermediate transferring belt 1 as a second image
bearing member which is in contact with the
20 photosensitive drums 11a-11d in their respective
primary transferring parts.

The photosensitive drums 11a-11d are disposed
along the direction of movement of the intermediate
transferring belt 1 in the order of the
25 photosensitive drum 11a for the first color (yellow)
located on the most upstream side, the photosensitive
drum 11b for the second color (magenta) located

nearest to and downstream of the photosensitive drum 11a, the photosensitive drum 11c for the third color (cyan) located nearest to and downstream of the photosensitive drum 11b, and the photosensitive drum 11d for the fourth color (black) located nearest to and downstream of the photosensitive drum 11c.

Each of the photosensitive drums 11a-11d in the present embodiment has an outer diameter of 30.0 mm and has on an aluminum cylinder a layer having a photosensitive material applied thereto.

As the intermediate transferring belt 1 which is an image bearing member, use can be made of an elastomer sheet or the like having plural-layer structure comprising a resin layer formed as a mold releasing layer on the toner carrying member surface side of resin film of urethane resin, fluorine resin, nylon resin, polyimide resin or the like, resin film consisting of one of these resins having carbon or electrically conductive powder dispersed therein to thereby effect resistance adjustment, or a base layer sheet of urethane rubber, NBR or the like.

The intermediate transferring belt 1 used in the present embodiment is one in which carbon is dispersed in polyimide and surface resistivity ρ_s has been adjusted to medium resistance of $1 \times 10^{12} \Omega$, and charges imparted to the intermediate transferring belt 1 at a transferring step or the like can be

attenuated without any special residual charge
eliminating mechanism being provided. This
intermediate transferring belt 1 is a single-layer
endless belt having a circumferential length of 1000
5 mm and a thickness of 100 μm .

Surface resistivity measurement was carried out
by making electrically conductive rubber into an
electrode in conformity with Japanese Industrial
Standard JIS-K6911 to thereby obtain a good
10 contacting property between the electrode and the
surface of the belt, and in addition, using a super-
high resistance ohmmeter (R8340 produced by Advantest
Co.). Measurement conditions were applied voltage =
100 V and application time = 30 s.

15 Also, the Young's modulus E of the intermediate
transferring belt 1 in the present embodiment is high
hardness of $9 \times 10^9 \text{ N/m}^2$, whereby the fracture or
creep of the belt is prevented and a longer life is
achieved.

20 The measurement of the Young's modulus was
based upon the tension elastic modulus measuring
method of JIS-K7127, and the thickness of a
measurement sample was 100 μm .

The intermediate transferring belt 1 is endless
25 as shown in Fig. 1, and is passed over three rollers
contained in the intermediate transferring belt 1,
i.e., a drive roller 1a, a supporting roller 1b and a

separation roller 1c. The drive roller 1a, the supporting roller 1b and the separation roller 1c are electrically grounded. The separation roller 1c is an opposed member (roller) opposed to a secondary
5 transferring roller 2 with the intermediate transferring belt 1 interposed therebetween, and supports the intermediate transferring belt 1.

Each of the drive roller 1a, the supporting roller 1b and the separation roller 1c is a roller
10 having an outer diameter of 29.8 mm and comprised of an aluminum mandrel having a diameter of 24.0 mm and a hydrin rubber layer having a layer thickness of 2.9 mm, and the roller resistance value thereof, is rendered into $1 \times 10^6 \Omega$ by the hydrin rubber being
15 resistance adjusted.

The roller resistance value was measured with the roller which is the object of measurement brought into contact with an aluminum cylinder having a diameter of 30 mm and being driven to rotate relative
20 to the aluminum cylinder, and by using a super-high resistance ohmmeter (R8340 produced by Advantest Co.). Measurement conditions were applied voltage = 100 V, application time = 30 s, contacting force = 9.8 N, and rotational peripheral velocity = 117 mm/s.

25 The intermediate transferring belt 1 is rotated in synchronism with the photosensitive drums 11a-11d at a predetermined process speed (in the present

embodiment, 117 mm/s) by the drive roller 1a. The
photosensitive drums 11a-11d are uniformly charged by
respective contact charging rollers 12a, 12b, 12c and
12d, and electrostatic latent images are formed
5 thereon by laser beams from respective scanners 13a,
13b, 13c and 13d modulated by an image information
signal transmitted from a host computer.

The intensity and application spot diameter of
the laser beams are set properly by the resolution
10 and desired image density of the image forming
apparatus, and the electrostatic latent images on the
photosensitive drums 11a-11d are formed by portions
to which the laser beams are applied being held at
light portion potential VL (about -150V), and
15 portions which are not so being held at dark portion
potential VD (about -650V) charged by the respective
contact charging rollers 12a-12d which are primary
chargers.

The electrostatic latent images reach portions
20 opposed to respective developing devices 14a-14d by
the rotation of the respective photosensitive drums
11a-11d, and are supplied with developers (toners)
charged to the same polarity (in the present
embodiment, the minus polarity) as the surfaces of
25 the photosensitive drums and are visualized thereby,
and developer images (toner images) are formed on the
photosensitive drums.

The developing devices 14a-14d in the present embodiment are developing apparatuses adopting a two-component developing process. Also, a developing bias in the present embodiment is a bias voltage
5 comprising an AC voltage superimposed on a DC voltage of a DC component = -400 V, an AC component = 1.5 kV_{pp}, a frequency = 3 kHz and a waveform = rectangular wave.

The toner images formed on the photosensitive drums 11a-11d are transferred onto the intermediate
10 transferring belt 1 by a primary transferring bias (in the present embodiment, constant current control of +15 μ A) being applied from primary transferring bias sources 16a-16d to primary transferring rollers 15a, 15b, 15c and 15d, respectively, which are in
15 contact with the back of the intermediate transferring belt 1 at respective primary transferring nips 20a-20d which are proximate or contact portions between the intermediate transferring belt 1 and the photosensitive drums 11a-
20 11d. At a stage whereat the intermediate transferring belt 1 has passed the primary transferring nip 20d with the photosensitive drum 11d, the formation of a four-color image on the intermediate transferring belt 1 is terminated, and
25 the primary transferring step is completed.

On the other hand, the surfaces of the photosensitive drums 11a-11d from which the primary

transfer of the toner images has been terminated are
cleaned by primary-untransferred toners, etc. being
removed by drum cleaning devices 17a, 17b, 17c and
17d comprising urethane rubber blades, and become
5 ready for the next image forming step.

Next, a transfer material (recording material)
M which is a transfer medium is taken out of feeding
means, not shown, and the transfer material M is
inserted into a secondary transferring nip part 22 by
10 the separation roller 1c and the secondary
transferring roller 2 as a transfer member being
brought into pressure contact with each other with
the intermediate transferring belt 1 interposed
therebetween. The reference numeral 23 designates
15 pressing means such as a spring, and the secondary
transferring roller 2 presses the separation roller
1c by this pressing means 23 with the belt 1
interposed therebetween. The secondary transferring
nip part 22 is a contact portion in which the
20 intermediate transferring belt 1 and the secondary
transferring roller 2 contact with each other.

At this time, a bias opposite in polarity to
the toners (in the present embodiment, constant
current control of +30 μ A) is applied to the
25 secondary transferring roller 2 by a secondary
transferring bias source 21, and the toner image is
secondary-transferred from the intermediate

transferring belt 1 to the transfer material M.

The transfer material M bearing the unfixed toner image thereon which has passed through the secondary transferring nip part 22 reaches a fixing
5 device 3, and is heated and pressurized, whereby a permanent fixed image is obtained. The surface of the intermediate transferring belt 1 from which the toner image has been transferred to the transfer material M has any secondary-untransferred toners
10 thereon removed by an intermediate transferring member cleaner 4 having a cleaning blade made of urethane rubber.

As described above, the intermediate transferring belt 1 used in the present embodiment is
15 one in which carbon is dispersed in polyimide to thereby adjust the surface resistivity ρ_s to medium resistance of $1 \times 10^{12} \Omega$, and charges imparted to the belt 1 at the transferring step or the like can be attenuated without any special residual charge
20 eliminating mechanism being provided, and the Young's modulus E is high hardness of $9 \times 10^9 \text{ N/m}^2$, whereby the fracture or creep of the belt is prevented and a longer life is achieved.

The secondary transferring roller 2 in the
25 present embodiment is a roller having an outer diameter of 22.0 mm comprised of an aluminum mandrel having a diameter of 14.0 mm and a foamed hydrin

rubber layer having a layer thickness of 4 mm, and
hydri rubber is resistance-adjusted to thereby
render the roller resistance value into $1 \times 10^8 \Omega$.
Also, as the secondary transferring roller 2, use is
5 made of a roller of somewhat low hardness of 35°
(Asker-C), and the nip width of the secondary
transferring roller 2 is widened to thereby prevent a
faulty image attributable to the conveyance shock of
the transfer material.

10 That is, the image forming apparatus according
to the present embodiment uses image bearing members
of high hardness and a transfer member of low
hardness, and improves the performance of the
conveyability of the transfer material and realizes a
15 longer life, but as described in connection with the
background art, such as image forming apparatus
having the transfer member of low hardness and the
image bearing members of high hardness becomes low in
the contact pressure of the transfer member and
20 therefore is liable to cause the color unevenness of
an image.

In the present embodiment, the contact pressure
 P [N/m^2] of the secondary transferring roller 2
against the intermediate transferring belt 1 is $4.8 \times$
25 10^4 N/m^2 . The contact pressure P is given as $P = F / (L$
 $\times W)$ from the lengthwise width L [m] of the secondary
transferring roller 2, the nip width W [m] between

the intermediate transferring belt 1 and the
secondary transferring roller 2 and the contacting
force F [N] of the secondary transferring roller 2
against the intermediate transferring belt 1 (see Fig.
5 2).

Also, the nip width W is obtained by applying
ink to the intermediate transferring belt 1 and
bringing the secondary transferring roller 2 into
contact therewith, and measuring the trace of the ink
10 adhering to the secondary transferring roller 2. As
the measuring method, the nip width W was determined
from the average of the measurements of the width of
the ink trace at five points in total, i.e., the
center of the roller, points of 50 mm from the center
15 toward the right and left lengthwise ends, and points
of 100 mm from the center toward the right and left
lengthwise ends. In the present embodiment, L was
set to $L = 0.30$ m, F was set to $F = 80$ N, and W was
0.0056 m.

20 Here, an effect in the present embodiment is
confirmed by Experimental Examples 1 to 7 in which
various conditions were changed. Experimental
Examples 1 to 7 are ones in which the contact
pressure P [N/m^2] of the secondary transferring
25 roller against the intermediate transferring belt and
the numerical value of the Young's modulus of the
intermediate transferring belt were changed.

Experimental Example 4 is the present embodiment (the first embodiment).

The contact pressure P was changed from 2.7×10^4 to 8.0×10^4 [N/m²]. The contact pressure P was
5 changed by changing the contacting force F [N] from 30 to 100 [N], and further changing the material hardness of the rubber layer of the secondary transferring roller, and changing the nip width W by the use of two levels of roller hardness, i.e., 35°
10 and 49° (Asker-C).

Table 1 below shows a list of the setting of the contacting force F , the nip width W and the secondary transferring roller hardness corresponding to the contact pressure P in the respective
15 experimental examples. These numerical values were measured by the measuring method in the above-described first embodiment.

Table 1

	Secondary Transferring Roller Hardness [°] (Asker-C)	Contacting Force F [N]	Transferring Nip Width W [mm]	Contact Pressure P [N/m ²]
Experimental Example 1	35	30	3.4	2.7×10^4
Experimental Example 2	35	50	4.5	3.5×10^4
Experimental Example 3	35	60	5.0	4.0×10^4
Experimental Example 4	35	80	5.6	4.8×10^4
Experimental Example 5	49	70	4.0	6.2×10^4
Experimental Example 6	49	90	4.8	7.3×10^4
Experimental Example 7	49	100	5.1	8.0×10^4

On the other hand, in these conditions, the Young's modulus of the intermediate transferring belt was changed from 4×10^6 to 9×10^9 [N/m²] by changing the material of the intermediate transferring belt.

In respective ones of Experimental Examples 1 to 7, as the above-described intermediate transferring belt, there were mounted (1) one having

a Young's modulus E of $9 \times 10^9 \text{ N/m}^2$ in which carbon was dispersed in polyimide, (2) one using a material of polyvinylidene fluoride (PVDF) having a Young's modulus of $2 \times 10^8 \text{ N/m}^2$, and (3) one using a material
5 of polyether sulfon (PES) having a Young's modulus of $2 \times 10^9 \text{ N/m}^2$.

In addition, particularly about a belt material of low Young's modulus, the expansion and contraction or creep of the belt occurs to a single layer,
10 whereby image magnification is unstable and the belt is weak to fracture and the life thereof is short, whereby the belt does not satisfy the function as the intermediate transferring belt and therefore, (4) a belt made into two-layer structure by spray-coating a
15 rubber sheet of NBR having a thickness of 3 mm with urethane resin (urethane resin coat) was used and mounted in respective image forming apparatuses. The Young's modulus of the urethane resin layer is $4 \times 10^6 \text{ N/m}^2$.

20 The PVD belt under item (2) and the PES belt under item (3) were formed into single-layer endless belts having a circumferential length of 1000 mm and a thickness of 100 μm by dispersing carbon to thereby adjust the surface resistivity ρ_s to $\rho_s = 1 \times 10^{12} \Omega$.
25 Also, the urethane resin coat belt under item (4) was formed into a two-layer endless belt having surface resistivity ρ_s of $1 \times 10^{12} \Omega$ on the toner bearing

surface side and having a circumferential length of 1000 mm and a thickness of 500 μm by dispersing carbon to thereby adjust the volume resistivity of NBR to $1 \times 10^6 \Omega \cdot \text{cm}$, and coating NBR with urethane resin having volume resistivity of $1 \times 10^9 \Omega \cdot \text{cm}$ to 30 μm .

In each experimental example, the dependency of the quality of image on the contact pressure P and the Young's modulus E was studied. Table 2 below shows the result of the comparative studies of images about Experimental Examples 1 to 7.

Table 2

Result of Evaluation of the Quality of Image
(Color Unevenness Level/Hollow Character Level)

	Contact Pressure P [N/m ²]	Young's Modulus E [N/m ²] of Intermediate Transferring Belt			
		4×10 ⁶	2×10 ⁸	2×10 ⁹	9×10 ⁹
Experimental Example 1	2.7×10 ⁴	△/○	×/○	×/○	×/○
Experimental Example 2	3.5×10 ⁴	○/○	○/○	○/○	×/○
Experimental Example 3	4.0×10 ⁴	○/○	○/○	○/○	△/○
Experimental Example 4	4.8×10 ⁴	○/○	○/○	○/○	○/○
Experimental Example 5	6.2×10 ⁴	○/○	○/○	○/○	○/○
Experimental Example 6	7.3×10 ⁴	○/○	○/△	○/△	○/△
Experimental Example 7	8.0×10 ⁴	○/○	○/×	○/×	○/×

- 5 The evaluation of the image color unevenness level in Table 2 was effected by evaluating the color unevenness of a blue (magenta and cyan) solid image, and the evaluation of the hollow character image (characters having a white part at the center of the

character) level was effected by evaluating the middle blank of a blue (magenta and cyan) line image having a width of 2 mm. The judgment of the above-described image color unevenness level and hollow
5 character image (characters having a white part at the center of the character) level was done by visual organic evaluation, and judgment standards were: O = no occurrence; Δ = a level practically posing no problem; and \times = a clearly seen level.

10 According to the present studies, the image color unevenness becomes better when the contact pressure P is increased, but the higher was the contact pressure P, the more was seen the occurrence of a hollow character image. Also, the higher was
15 the Young's modulus E, the more was aggravated the image color unevenness.

Here, description will be made of phenomena called the image color unevenness and the hollow character image.

20 (1) Image Color Unevenness: The image color unevenness is a phenomenon remarkably observed in solid images chiefly of secondary colors such as blue, red and green. For example, in blue, magenta and cyan toner images are in a state in which the cyan
25 toner is superposed on the magenta toner, on the intermediate transferring belt.

The cyan toner superposed on the magenta toner

is substantially uniformly transferred onto the transfer material because the magenta toner acts as spacer particles for the intermediate transferring belt. On the other hand, the magenta toner

5 underlying the cyan toner on this intermediate transferring belt partly remains on the intermediate transferring belt at the secondary transferring step due to the adhering force between the magenta toner and the intermediate transferring belt.

10 If this residual magenta toner becomes non-uniform depending on locations, cyan is substantially uniform in the final blue solid image on the transfer material, whereas magenta becomes non-uniform. Accordingly, an area of a color near to cyan exists
15 in the blue solid image and it is seen as color unevenness.

That is, the image color unevenness is the phenomenon that of toner images of a plurality of colors superposed and formed on the intermediate
20 transferring belt, only a toner image of a color adjacent to the surface side is partly transferred to the transfer material, and this becomes color unevenness.

The inventor thinks as follows about the
25 mechanism of the dependency of this color unevenness on the contact pressure P.

The cause of the occurrence of the color

unevenness is considered to reside in that due to the unevenness of the surface of the transfer material, the surface of the transfer material and the surface of the intermediate transferring belt cannot come
5 into close contact with each other, and depending on locations air gaps exist between the surface of the transfer material and the surface of the intermediate transferring belt.

Unless the reversal of the polarity of the
10 toners occurs, the amount of toners transferred from the intermediate transferring belt to the transfer material becomes greater when the transferring electric field applied to the toner layer is greater.

At a location whereat the contact between the
15 surface of the transfer material and the surface of the intermediate transferring belt is bad and an air gap exists between the toner layer on the intermediate transferring belt and the surface of the transfer material, the transferring electric field
20 originally applied to only the toner layer is divided by the air layer, whereby the electric field applied to the toner layer is weakened, and the amount of toners residual on the intermediate transferring belt becomes great. Thereby, the contact state between
25 the surface of the transfer material and the surface of the intermediate transferring belt becomes non-uniform depending on locations, whereby the

untransferred toners are also considered to become non-uniform.

Consequently, in the present embodiment, the contact pressure P is increased to crush the unevenness of the surface of the transfer material M to thereby uniformize the contact state between the surface of the transfer material M and the surface of the intermediate transferring belt and uniformize the residual toners on the intermediate transferring belt 1, whereby the color unevenness is improved.

Also the inventor thinks as follows about the mechanism of the dependency of the color unevenness on the Young's modulus E .

The cause of the occurrence of the color unevenness, as described above, is considered to reside in that due to the unevenness of the surface of the transfer material, the surface of the transfer material and the surface of the intermediate transferring belt cannot uniformly come into close contact.

When the Young's modulus of the intermediate transferring belt is high, the surface of the intermediate transferring belt does not follow the unevenness of the surface of the transfer material because the surface of the intermediate transferring belt is hard and therefore, an air gap is formed between the toner layer on the intermediate

transferring belt and the surface of the transfer material in a wider area. Thus, it is considered that if the Young's modulus of the intermediate transferring belt is higher, the color unevenness is
5 aggravated.

(2) Hollow Characters Image: The hollow character image is a phenomenon remarkably observed line images chiefly of secondary colors such as blue, red and green.

10 The magenta and cyan toner images constituting blue are in a state in which the cyan toner is superposed on the magenta toner, on the intermediate transferring belt. If at the secondary transferring step, of the magenta toner underlying the cyan toner
15 on this intermediate transferring belt, chiefly the central portion of the line image is residual on the intermediate transferring belt, whereby in the final line image on the transfer material, the cyan toner is substantially uniform, whereas the magenta toner
20 becomes little at the central portion of the line. Thus, an area of a color near to cyan exists in the central portion of the blue line image, and the central portion of the line image is seen as a blank. This phenomenon is the center blank image.

25 The reason why the amount of residual toners is particularly great in the central portion of the line image is considered to be that when the toners are

compressed by the pressure in the nip between the transfer material and the intermediate transferring belt, pressure is most applied to the central portion of the line and the adhering force between the toners
5 in the central portion becomes particularly high.

The mechanism of the dependency of the center blank image on the contact pressure is considered as follows. The cause of the occurrence of the center blank image resides in that the toners are compressed
10 by the pressure in the nip between the transfer material and the intermediate transferring belt, whereby the adhering force between the toners is increased, and it is considered that as the contact pressure becomes great, the adhering force between
15 the toners is increased, whereby the center blank image level is aggravated.

To adopt a material of low Young's modulus for the intermediate transferring belt, it is necessary to adopt a plural-layer construction, and this
20 complicates the belt manufacturing process and results in the high cost of the belt.

Consequently, in the present invention, for a longer life and lower costs, use is made of an intermediate transferring belt of high hardness, and
25 the present invention is characterized in that without the Young's modulus E of the intermediate transferring belt being lowered, the contact pressure

is adjusted to an appropriate value to thereby prevent the color unevenness and center blank phenomena described above.

Accordingly, from the result of the comparative studies shown in Table 2, the inventor has been able to confirm that Experimental Examples 3 to 6 are effective against the color unevenness and the center blank, and the contact pressure P is set to the image of $4.0 \times 10^4 \leq P \text{ [N/m}^2\text{]} \leq 7.3 \times 10^4$, and this is effective to lower the occurrence levels of the color unevenness and center blank image and prevent a faulty image when the Young's modulus of the intermediate transferring belt 1 is $2 \times 10^8 \leq E \text{ [N/m}^2\text{]} \leq 9 \times 10^9$.

Consequently, in the present embodiment, setting is made such that the Young's modulus E of the intermediate transferring belt 1 is within the range of $2 \times 10^8 \leq E \text{ [N/m}^2\text{]} \leq 9 \times 10^9$ and the contact pressure P is within the range of $4.0 \times 10^4 \leq P \text{ [N/m}^2\text{]} \leq 7.3 \times 10^4$.

Thus, the present embodiment can achieve a long life and low costs by using an intermediate transferring belt of high hardness of which the Young's modulus E is $10^8 \leq E \text{ [N/m}^2\text{]} \leq 9 \times 10^9$, and even if this intermediate transferring belt of high hardness is used, a faulty image such as the color unevenness or the center of blank can be prevented by

setting the contact pressure P between the intermediate transferring belt and the transferring member to the range of $4.0 \times 10^4 \leq P \text{ [N/m}^2\text{]} \leq 7.3 \times 10^4$.

5 (Second Embodiment)

A second embodiment of the present invention will now be described. This embodiment is basically similar in construction to the first embodiment, and portions thereof differing from those of the first
10 embodiment will hereinafter be described.

As shown in Fig. 4, in the present embodiment, as an intermediate transferring belt 24, use is made of a single-layer endless belt having a circumferential length of 1000 mm and a thickness of
15 100 μm in which carbon is dispersed in polyimide and both of a toner bearing surface side and a back side are adjusted to surface resistivity $\rho_s = 1 \times 10^{12} \Omega$.

Also, the Young's modulus E of the intermediate transferring belt 24 is $9 \times 10^9 \text{ N/m}^2$.

20 The contact pressure $P \text{ [N/m}^2\text{]}$ of the secondary transferring roller 2 against the intermediate transferring belt 24 is $4.8 \times 10^4 \text{ N/m}^2$ as in the first embodiment.

As Experimental Examples 8 to 14, the contact
25 pressure of the secondary transferring roller against the intermediate transferring belt and the surface resistivity of the intermediate transferring belt

were changed. The contact pressure was changed from 2.7×10^4 to 8.0×10^4 N/m². Experimental Example 11 is the present embodiment (the second embodiment).

In the respective experimental examples, as in
5 the case of Experimental Examples 1 to 7, the
contacting force F [N] was changed from 30 to 100 [N]
and further, the material hardness of the rubber
layer of the secondary transferring roller 2 was
changed to thereby use two levels 35° and 49°
10 (Asker-C) as the roller hardness, thereby adjusting
the contact pressure P .

Also, the amount of carbon dispersed in
polyimide was adjusted to thereby change the surface
resistivity ρ_s of the intermediate transferring belt
15 from 1×10^6 to equal to or greater than 1×10^{15} Ω .

The intermediate transferring belt of which the
surface resistivity ρ_s is "equal to or greater than 1×10^{15} Ω " has surface resistivity of equal to or
greater than 1×10^{15} Ω which is the measurement limit
20 by the background noise of the above-described
surface resistivity measuring system and therefore,
here it is expressed as equal to or greater than 1×10^{15} Ω . The measurement of the surface resistivity
was effected by the method described in the first
25 embodiment.

The intermediate transferring belt in each
experimental example was a single-layer endless belt

having a circumferential length of 1000 mm and a thickness of 100 μm as in the present embodiment.

In Experimental Examples 8 to 14, the dependency of the quality of image on the contact
5 pressure P and on the surface resistivity ρ_s was studied. The result of the comparative studies of an image about the respective experimental examples is shown in Table 3 below.

Table 3

	Result of Evaluation of Quality of Image (Color Unevenness Level/Hollow Character Level)						
	Contact Pressure P [N/m ²]	Surface Resistivity ps [Ω]					
		1 \times 10 ⁶	1 \times 10 ⁸	1 \times 10 ¹⁰	1 \times 10 ¹²	1 \times 10 ¹⁴	Equal to or greater than 1 \times 10 ¹⁶
Experimental Example 8	2.7 \times 10 ⁴	x/o	x/o	x/o	x/o	x/o	o/o
Experimental Example 9	3.5 \times 10 ⁴	x/o	x/o	x/o	x/o	Δ /o	o/o
Experimental Example 10	4.0 \times 10 ⁴	Δ /o	o/o	o/o	o/o	o/o	o/o
Experimental Example 11	4.8 \times 10 ⁴	Δ /o	o/o	o/o	o/o	o/o	o/o
Experimental Example 12	6.2 \times 10 ⁴	o/x	o/o	o/o	o/o	o/o	o/o
Experimental Example 13	7.3 \times 10 ⁴	o/ Δ	o/ Δ	o/ Δ	o/ Δ	o/ Δ	o/o
Experimental Example 14	8.0 \times 10 ⁴	o/x	o/x	o/x	o/x	o/x	o/x

According to the present studies, the color unevenness became good when the contact pressure was increased, and the higher was the surface resistivity ps of the intermediate transferring belt, the better

became the color unevenness.

Also, in an intermediate transferring belt of $1 \times 10^6 \Omega$, it never happened that even if the contact pressure was increased, good color unevenness and
5 hollow characters were compatible.

An intermediate transferring belt of equal to or greater than $1 \times 10^{15} \Omega$ is great in the time constant of charge attenuation and charges imparted to the surface thereof are residual thereon and
10 therefore, during image forming, a corona charger, not shown, was installed at a location on the intermediate transferring belt downstream of the cleaning blade 4 and upstream of the photosensitive drum 11a for the first color, and an image forming
15 was effected while applying an AC bias of 10 kV_{pp}, 1 kHz and sine wave to thereby eliminate the residual charges on the intermediate transferring belt.

The judgment of the image color unevenness and center blank image levels in Table 3 was effected in
20 a manner similar to that described in the first embodiment. The inventor thinks as follows about the mechanism of the dependency of the color unevenness on the surface resistivity ρ_s .

The cause of the occurrence of the color
25 unevenness is considered to be that the amount of toners residual on the intermediate transferring belt is great at locations whereat due to the unevenness

of the surface of the transfer material, the surface
of the transfer material and the surface of the
intermediate transferring belt cannot uniformly come
into close contact with each other and air gaps exist
5 between the surface of the transfer material and the
surface of the intermediate transferring belt.

By heightening the surface resistivity ρ_s , the
difference in the transferring electric field applied
to the toner layer in areas wherein the air gaps
10 exist and areas wherein the air gaps do not exist can
be made small, and the difference in the amount of
untransferred toners in the areas wherein the air
gaps exist and the areas wherein the air gaps do not
exist can be made small. Thereby, the residual tones
15 on the intermediate transferring belt become uniform
and the color unevenness is improved.

From the above-described result of the
comparative studies, the inventor has been able to
confirm that Experimental Examples 10 to 13 are
20 effective for the color unevenness and the center
blank and in a case where the surface resistivity ρ_s
[Ω] of the intermediate transferring belt is 1×10^8
 $\leq \rho_s \leq 1 \times 10^{15}$, the occurrence level of the color
unevenness and the center blank image can be rendered
25 into a level which practically poses no problem, by
setting the contact pressure P [N/m^2] to the range of
 $4.0 \times 10^4 \leq P \leq 7.3 \times 10^4$, without having any special

residual charge eliminating device for the intermediate transferring belt.

Consequently, in the present embodiment, setting is done such that the surface resistivity ρ_s [Ω] of the intermediate transferring belt 24 is $1 \times 10^8 \leq \rho_s \leq 1 \times 10^{15}$ and the contact pressure P [N/m²] is within the range of $4.0 \times 10^4 \leq P \leq 7.3 \times 10^4$.

As described in the first embodiment, again in the present embodiment, the occurrence of the color unevenness and the center blank can be suppressed even if the Young's modulus E of the intermediate transferring belt is high hardness of $2 \times 10^8 \leq E \leq 9 \times 10^9$.

While in the above-described embodiments, the intermediate transferring belt has been described with respect to a single-layer one, the present invention is also applicable to an intermediate transferring belt having a plurality of layers having a Young's modulus of high hardness on at least the surface layer thereof adjacent to the transferring member.

While in the aforescribed embodiments, a color laser printer having photosensitive members which are image bearing members for four colors has been described by way of example as the image forming apparatus, the present invention is not restricted thereto, but may be an image forming apparatus such

as a facsimile apparatus or a copying machine, and the number of the photosensitive members may be one. The present invention is not restricted to a color image forming apparatus, but is also applicable to an apparatus having a single image bearing member and effecting single-color image formation.

Also, while in the aforescribed embodiments, description has been made of a case where an intermediate transferring belt is utilized as an image bearing member, a secondary transferring roller is utilized as a transfer member for transferring a formed image to a transfer material, and the image is secondary-transferred from the intermediate transferring belt to the transfer material, the present invention is not restricted thereto, but may also be applied to a transfer member utilizing a photosensitive drum or a photosensitive belt as an image bearing member, and transferring a formed image to other medium such as a transfer material or an intermediate transferring member. Accordingly, the present invention can also be applied in an image forming apparatus provided with no intermediate transferring member.

As described in the first embodiment and the second embodiment, there can be provided an image forming apparatus in which the contact pressure P [N/m²] between a transfer member such as a

transferring roller and an image bearing member such
as an intermediate transferring belt is set to $4.0 \times 10^4 \leq p \leq 7.3 \times 10^4$ to thereby prevent color
unevenness and hollow characters even if use is made
5 of an image bearing member of a long life and low
costs and a transferring member of low hardness. In
this case, the center blank and the color unevenness
can be prevented even if the surface resistance of
the image bearing member is relatively high.

10 As described above, the image forming apparatus
of the present invention enables an image bearing
member and a transfer member to be applied thereto in
a wide range, and the present invention can provide
an image forming apparatus of low costs and a long
15 life which prevents the image color unevenness and
the image hollow character in the image forming
process even if use is made of an image bearing
member of high hardness.

While the embodiments of the present invention
20 have been described above, the present invention is
in no way restricted to the above-described
embodiments, and all modifications are possible
within the technical idea of the present invention.